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CURRENT DENSITY MAPPING OF CADMIUM SULFIDE THIN-FILM SOLAR CELLS

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Cleveland, Ohio

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16. Abstract

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SUMMARY

A diagnostic technique was developed to examine cadmium sulfide thin-film solar cells and rapidly determine the location of current nonuniformities. This was accomplished by measurement of the magnetic field normal to the solar cell. The results were displayed in a graphic form allowing visual location of nonuniform regions.

INTRODUCTION

Degradation of the cadmium sulfide (CdS) thin-film solar cells (ref. 1) is thought to be caused by local defects. These defects show up as areas of higher temperatures or hot spots (ref. 2). Such areas have been found by thermographic analysis of the cell. The hot spot areas are presumed to be formed by the I^2R heating caused by shorting paths in the problem areas. The magnetic fields in the problem areas would be expected to be nonuniform due to the change in local current density.

This report describes an apparatus which displays the nonuniformity in current density by means of magnetic field measurements. Since the purpose of the apparatus was to locate problem areas in solar cells, no attempt was made to obtain quantitative measurements of the current density. The apparatus scans the surface of a CdS solar cell and produces a graphic map of the magnetic fringe field over the scanned area. This map can be used to interpret the current paths in the scanned area.

This method produces a nondestructive examination of the cells and was used on cells while they were illuminated to determine their current distribution patterns before and after degradation.

APPARATUS

The basic operation of the current mapping apparatus involves the movement of a small pickup coil across a sample area to sense the normal component of the ac magnetic field at the surface of the sample. Figure 1 shows schematically how the several pieces of equipment were interconnected.

To accomplish the scanning, the sample fixture was placed above an X-Y recorder, the scan recorder, which had its pen replaced by a pickup coil. With the pickup coil in close proximity to the sample, the X-Y recorder was programmed to traverse the whole area systematically by the scan control unit. Also controlled was another X-Y recorder, the mapping recorder, which had added to its Y axis a step function and the amplified and modified signal from the pickup coil. The output of the mapping recorder was a qualitative representation of the current flow patterns. In the process of assembling the equipment into a workable unit, four main work areas were encountered and are now described.

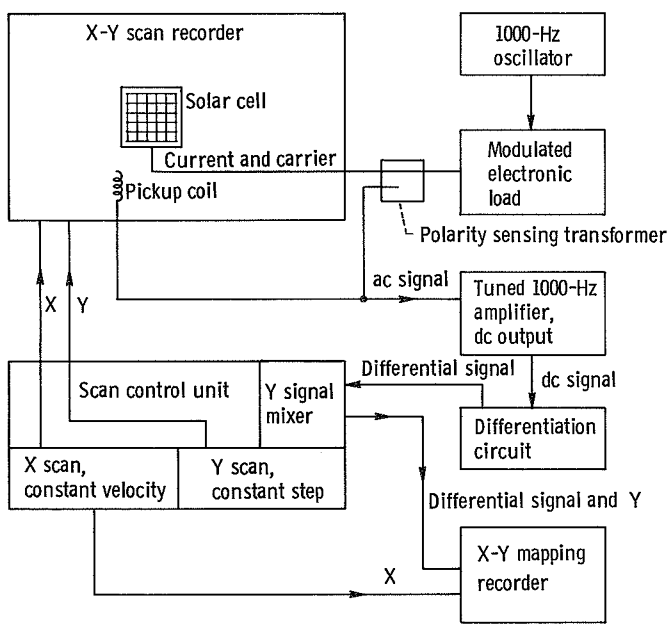


Figure 1. - Block diagram showing current density mapping system.

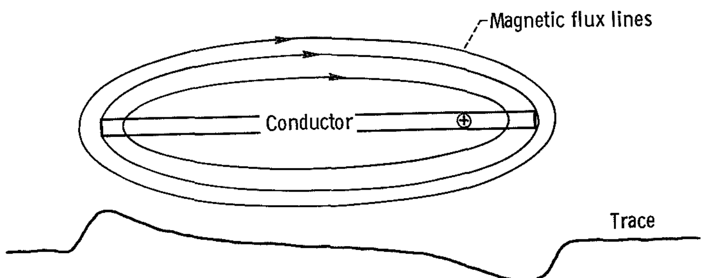
Field Detection and Noise

To readily detect the magnetic field of a sample a 1000-hertz carrier current is passed through the sample. This carrier sets up a magnetic field around the sample which is detected by a small multiturn pickup coil.

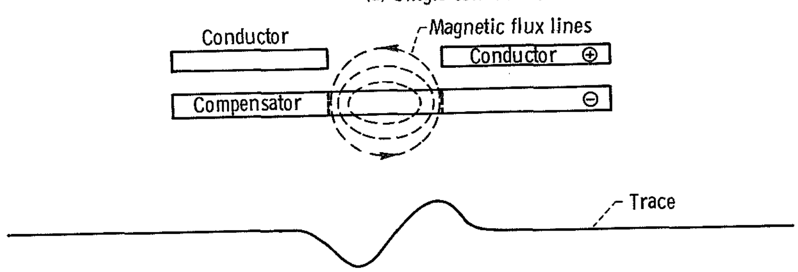
The signal from the pickup coil is fed to an amplifier tuned to the same frequency. This method assures amplification of only the 1000-hertz signal and rejection of other frequencies and radiated noise.

Uniform Response

The magnetic field over a flat uniform conductor is not uniform, and the trace from the pickup coil would appear as shown in figure 2(a). To obtain a uniform trace from a uniform return current path of the same width as the sample was placed below the sample, as shown in figure 3. The magnetic field due to this return path, or compensator, opposes the field due to the current through a uniform sample. The signal from the pickup coil then is near zero because of algebraic addition of fields when the compensator is close to the sample. When the sample is not uniform, the resulting nonuniformity in the magnetic field is not cancelled, and the pickup coil gives a signal representative of the net flux, as in figure 2(b).



(a) Single conductor.



(b) Conductor with compensator.

Figure 2. - Uniform conductor normal magnetic flux traces.

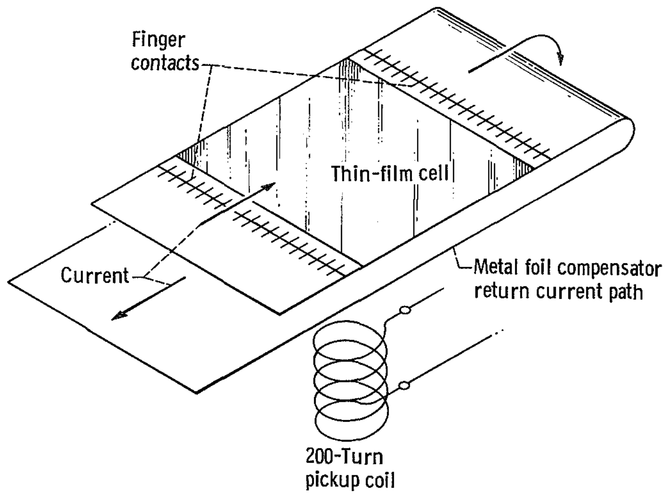


Figure 3. - Test fixture for current density mapper.

Polarity Discrimination

The amplitude of the 1000-hertz signal from the pickup gives a measure of the magnitude of the magnetic field, but not the polarity. In order to incorporate polarity into the measured signal, a signal is tapped from the current supplied to the sample by means of the polarity sensing transformer (fig. 1) and added to the pickup coil signal. Reversals in polarity of the measured field will put the pickup coil signal into or out of phase with the carrier signal. The amplitude of the signals will add or subtract depending on the polarity of the field.

Differentiation Circuit

The signal from the pickup coil, modified as described above, represents the normal component of the magnetic field at the sample surface. For a sample with a hole this signal would give a trace like that in figure 2(b). It was found that differentiation of this signal gave a trace that was easier to interpret and was more representative of the current pattern in the sample. Figure 4 shows the trace obtained across a hole in the sample. Although the differentiated signal is not an exact measure of the local current in the sample, the trace gives a gross representation of the current pattern.

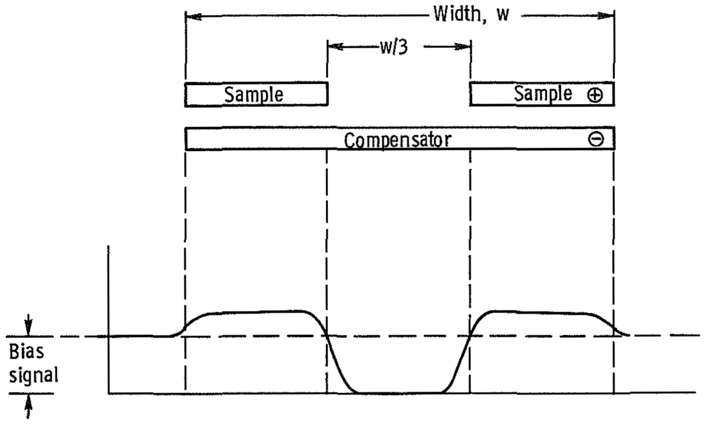


Figure 4. - Normal magnetic trace of sample with hole.

Sample Traces

A series of traces across the surface of a sample depicts the general features of the current pattern through the sample. A uniform sample has a very even current distribution which is indicated as a series of straight lines. Current concentrations are indicated by traces rising above the average value. Conversely, current deficient areas have the appearance of depressions. After some experience these undulations displayed on the maps can easily be interpreted to identify nonuniformities in the sample.

Current density maps of two prepared samples are shown in figures 5 and 6. The current level in the hole areas are considerably lower than in the remaining sample.

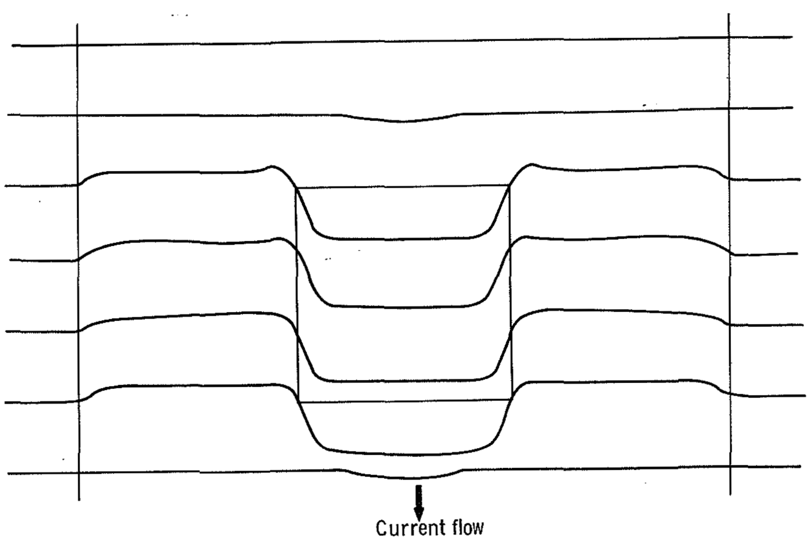


Figure 5. - Average current map of slot.

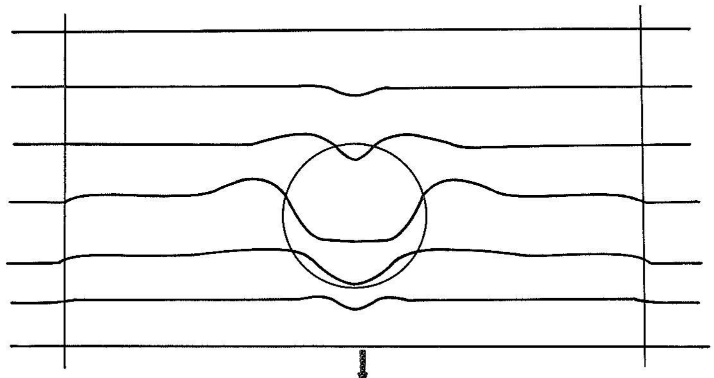


Figure 6. - Average current map of hole.

Note that the current rises in the immediate vicinity of the holes, as would be expected.

Figure 7 is a photograph of a CdS solar cell with a well defined defect. The defect, a burn hole in the cell, clearly shows in the current density map of figure 8.

This same cell also contains a fabrication flaw near the righthand edge of the cell (fig. 8). In this flaw area there is no substrate conductor, CdS, or grid wires. It is, in effect, an electrical hole in the cell. However, the cell edge signal somewhat obscures this defect even though the general resolution of the system is adequate to map a flaw of this size.

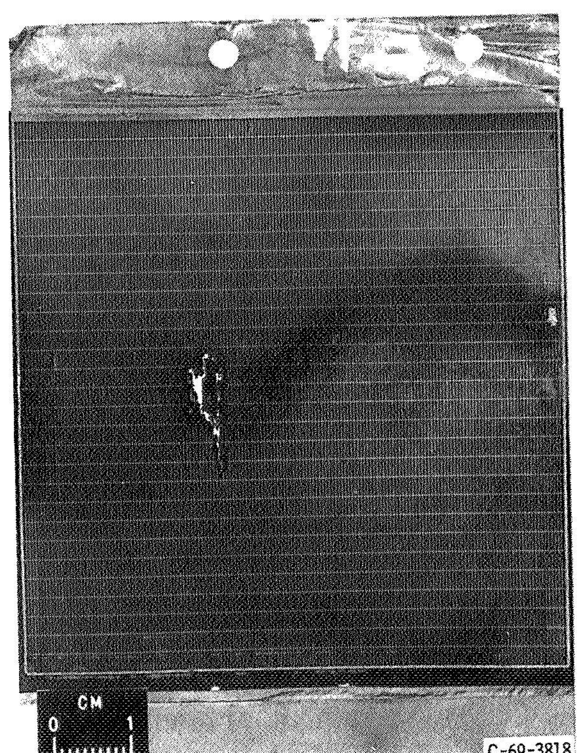


Figure 7. - Cadmium sulfide solar cell with burn hole.

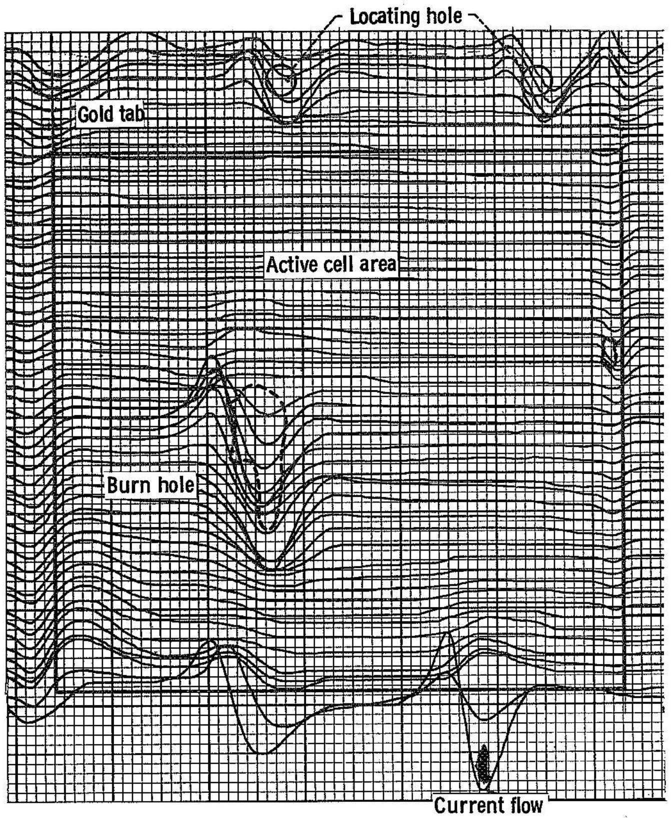


Figure 8. - Average current map of damaged cell.

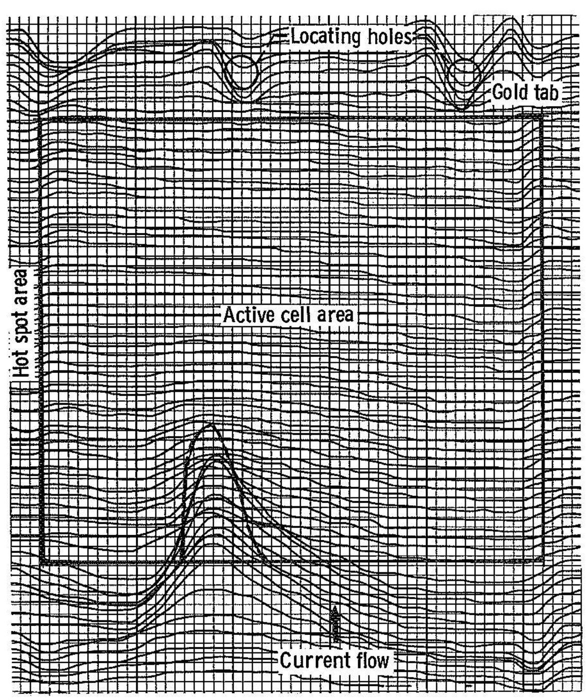


Figure 9. - Solar cell with hot spot.

Figure 9 is a current density map of a cell with a known hot spot. The hot spot, outlined by the dashed curve in figure 9, was located by means of an infrared viewing device. The current density map confirms that the hot spot is a high current region.

CONCLUDING REMARKS

The current density mapper can be a valuable diagnostic tool for investigating CdS thin-film solar cells. Using this technique electrical problems due to internal nonuniform current patterns can be detected. This nondestructive testing can be especially useful because the cell can be tested under typical operating conditions.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, October 29, 1969,
120-33.

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